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An Information Summary on Arctic Grayling From the Williston Reservoir Watershed With Data Gap Analysis And Recommendations

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The Peace/Williston Fish & Wildlife Compensation Program is a cooperative venture of BC Hydro and the provincial fish and wildlife management agencies, supported by funding from BC Hydro. The Program was established to enhance and protect fish and wildlife resources affected by the construction of the W.A.C. Bennett and Peace Canyon dams on the Peace River, and the subsequent creation of the Williston and Dinosaur Reservoirs.

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INTRODUCTION

Limited fisheries information is available on Arctic grayling prior to the formation of the reservoir, but in the mid and late 1970's this species was very numerous and widespread in the watershed. Then in the early 1980's there was a reported severe decline for no obvious reason. Arctic grayling populations in all small and medium sized streams flowing directly into the reservoir had disappeared by the late 1980's. Only those stocks utilising the largest river systems remain. Initially the decline was blamed on the reservoir flooding out key spawning and rearing areas, but this does not explain how this species could apparently flourish for over a decade and then disappear abruptly. In the early years of the reservoir many fish species flourished. The newly flooded areas released nutrients and the floating mats of timber provided cover for fish as well as a habitat for an invertebrate community. By the early 1980's the nutrient levels in the reservoir were probably declining, and much of the floating timber had been cleared from the reservoir. This would have resulted in a decline in the amount of food available in the reservoir, a loss of cover, and greatly improved access for anglers to the stream mouth areas, where large numbers of grayling congregated.

A review of the literature on Arctic grayling reveals some common themes, such as extreme vulnerability to overfishing, an inability to compete with introduced species, vulnerability to changes in stream flows, complex and frequently site specific life history patterns, and long, complex migrations to spawning, feeding, and overwintering areas. Vincent (1962) in his paper detailing the demise of the species from Michigan and Montana suggests that Arctic grayling are "specialists" that have adapted to utilise the resources available in specific environments and that they tend to form genetically isolated populations. This specialisation is how grayling can exist in very high numbers in relatively unproductive habitats. However, may also lead to an inability to adapt to changes in the environment.

The environment in Williston Watershed has been dramatically changed, and overfishing may have seriously depleted many populations. No new species have be introduced to the area, but the formation of the reservoir and industrial activities may have changed the environment to such an extent that species which formerly could not compete with grayling now have a competitive advantage. The reservoir provides habitat that is generally warmer and has a longer growing season than was previously available. This is advantageous to species such as rainbow trout whose populations were potentially restricted by the cold temperatures and short growing season in much of this watershed. The reservoir may also interfere with migration patterns. Fish that overwinter in the reservoir may now travel up to 200 km in a lake environment rather than overwinter in or just a few km downstream from their natal stream. This would certainly increase the propensity for fish to stray or not return.

Some populations such as the Table River (which flows into the Parsnip River) stocks have survived severe habitat degradations. Yet other stocks such as those of Davis River (which flows into the reservoir) have had minimal habitat impacts, and yet have disappeared. This suggests that the reservoir may play a key role in the decline of many stocks. In other systems, that are not be affected by the reservoir, grayling populations have been extirpated (Misinchinka R.) or declined severely (Pine and Moberly R's), particularly near road access, suggesting angling pressure may have played a major role.

It may not be possible to determine the exact cause of the disappearance of so many stocks utilising the medium and small systems entering the reservoir. But it was probably a combination of overfishing, and an inability of at least one life history stage to compete in the reservoir once productivity began to decrease and the cover provided by the floating log mats was removed.
The purpose of this report for the PWFWCP Fish Technical Committee is to:

- Provide a historical background on Arctic grayling in Williston Watershed.
- Summarise what activities have been undertaken by the PWFWCP which were directed towards Arctic grayling.
- Summarise life history information available from the literature, what has been found in Williston Reservoir, and what are some of the more important information gaps.
- Discuss possible factors limiting Arctic grayling populations in this watershed.
- Recommend an approach to effectively conserve and enhance Arctic grayling stocks and their habitats in the program area.

CHRONOLOGY OF ARCTIC GRAYLING WORK IN THE WILLISTON RESERVOIR WATERSHED

Pre 1988

(References 4,10,11,12,13,20,91)

- Little information is available on grayling prior to the construction of the W.A.C. Bennett Dam in 1968 and the formation of Williston Reservoir.
- Anecdotal information suggests that there was limited utilisation of the Finlay and Peace River mainstems because of the glacial nature of these streams but that grayling were distributed through out the watershed.
- After the formation of the reservoir grayling were the most numerous game fish in most streams. They were found in low and high gradient streams and were the only species noted as abundant in high gradient areas.
- 1974-5 - grayling comprised 13% of the gamefish captured by gill nets in the reservoir.
- 1977 – a creel survey found 58% and 23% of the angler harvest from the Peace Reach and Finlay Forks area was grayling.
- Grayling utilised the entire reservoir, but the largest concentrations were primarily near the stream mouths.
- Many grayling using smaller streams returned to the reservoir after spawning.
- Many grayling overwintered in the reservoir and large numbers were captured at the dam during the winter.
- Angler catches, particularly in the stream mouth areas were reported to be incredibly large.
- Residents report that the decline of arctic grayling stocks was sudden and in about 1981 to1983 but there is no documentation on the status of the populations between 1977 and 1988.

1988

1988 **Williston Reservoir Gill Netting Studies**

- Arctic grayling declined from 13% of the sportfish caught in 1975 to <<1% in 1988.(8% to <<1% using comparable data taken from the same gill netting sites.)

1988 **Creel Survey**

- Arctic grayling declined from 58% of the sportfish catch from the Peace Reach in 1977 to <1% in 1988.

1989

1989-1993 **Stream Inventories:**

- Arctic grayling have disappeared from nearly all of the streams surveyed. Two grayling in total were found in all the Peace Reach streams. Grayling are significantly smaller (P<.05 students T Test) now at age three and four than in the mid 1970's.

Public meetings held in 1989 and 1990.

- Strong public pressure (in Mackenzie) to close the grayling fishery and Arctic grayling were a very high priority for the public.

1990

1990 **The Williston Lake Fisheries Compensation Program Management Plan was developed with specific goals and objectives by fish species and by habitat type.**

Goal: "Preserve or increase Arctic grayling stocks within tributary streams of the watershed.

Objective: "Maintain and enhance the angling opportunities for Arctic grayling in the Williston Watershed".

Strategies: Determine distribution and relative abundance of Arctic grayling within the watershed.

- Gather life history data and determine what factors are limiting Arctic grayling production.

- Develop a list of potential enhancement options from the literature.
- Implement small pilot projects to determine the feasibility of creating an enhanced grayling fishery.

1991

1991-1999 Mesilinka Stream Fertilisation Program

Objective: This project was initiated to test the feasibility of stream fertilisation as an Arctic grayling enhancement.

- Stream fertilisation has had a positive affect on Rainbow trout and mountain whitefish populations.
- Arctic grayling populations have had a more modest positive response to stream fertilisation.
- Fertilisation may be benefiting competing species more than grayling populations in this system.
- Additional time will be required to determine the long term affects on grayling populations.

1991 Arctic grayling literature review

- This project is ongoing and the information gathered was provided to Dr. Northcote in 1992 and is contained in his report.

1992

1992 Arctic grayling Enhancements Review

This project was conducted as a direct result of public concern over the dramatic decline of arctic grayling populations. The contract was designed to determine:

- What enhancement and management options are available for Arctic grayling?
- What activities have been used in other areas, which activities have been successful, which have failed and why?
- What are the long term ramifications of enhancements and which are appropriate in the Williston Watershed?

This review provides a good life history background (from the literature) but does not strongly support any specific enhancements. The report does suggest reduced catch limits, habitat protection and long term life history studies aimed at filling gaps in the knowledge on this species (Northcote 1993).

The information Dr. Northcote recommended we gather includes:

Reproductive Biology

- Definition of the *major spawning areas, habitat and timing* should be made for a set of index streams, river and lake types within the watershed. Are specific stream types (*temperature*, gradient, flow regime, substrate, cover, nutrient levels etc.) necessary for optimal grayling production.
- Experimental tests of male spawning territory size, conditions, requirements, compressibility are needed.
- Experimental work on the effects of spawning substrate size, sedimentation, disturbance related to hatching, emergence and dispersal success should be started.

Early Rearing Habitat

- Experiments are needed to determine the importance of and use of stream side "lateral" habitat for emergent grayling larvae and fry.
- Tests should be made to assess the main factors setting territory size and permanency in grayling fry and juveniles: food supply, *substrate diversity and /or complexity*.

Feeding Biology

- The importance of prey abundance, size availability and diversity on fry growth and survival.

Age and Growth

- Age and growth rate should be validated in a few index populations representing a range of environmental conditions; several ageing methods should be tested to check for missing annuli at early and late growth stages.
- Effects of angling pressure on age class structure and fecundity should be examined in a set of index streams representing high and low rates of exploitation.
- Effects of social hierarchies and territorial behaviour on grayling growth rates should be tested.

Migration and Homing

- The extent, importance and fidelity of grayling migration *between spawning feeding and wintering habitats* needs study in a few index populations.

Stocks

- Serious management of grayling populations must be conducted at the stock level. A first step would be to examine the degree of stock partitioning and fidelity within a few index waters in the watershed using the best available

techniques for stock recognition (meristic, physiological, genetic and behavioural.

Population Density, Dynamics and Control

- The important parameters of grayling population biology need to be monitored in a few index waters to determine the interaction between main factors setting grayling abundance (space, food, competition, predation, parasitism, disease). A productive approach might involve correlative (multiple regression) studies to key habitat features (sediment levels, overwinter sites, flow regime, nutrient levels etc.) combined with experimental manipulations.

1992 &1993 Arctic grayling Transplant

Objective: Create a potential "genetic reserve" for the Nation River grayling stocks and gather life history information.

- Adult grayling (58 & 25), captured from the Nation River were transplanted into Little Calais Lake, a barren headwater lake in that system.
- It was noted that there were fewer fish available and that the fish were smaller in the second year.
- Reports were received that grayling (probably the transplanted fish) were captured by anglers in the Nation River upstream from Chuchi Lake. Local residents reported that grayling had never been seen in this area before.
- 1996 - a brief survey was conducted on Little Calais Lake and no grayling were captured.
- 1998 - a small lake evaluation was conducted on Calais and Little Calais Lakes. No Arctic grayling were captured but rainbow trout are now present (from the stocking of Albert Lake).

1993

1993 Support from Industry

- The local mill in Mackenzie proposed constructing and operating a hatchery in Mackenzie for the propagation of local Arctic grayling stocks.
- A report was prepared for the chair of the Technical Committee to present to upper management staff of the Ministry to deal with this issue. The report did not recommend the development of a grayling hatchery at that time, because there were too many questions to be answered before a hatchery was considered.

1994

1994 Nation River Arctic Grayling Traps

Objective: Gather life history data and determine the status of Arctic grayling stocks.

- Traps were operated on two tributary streams that local residents indicated had historically supported substantial grayling populations.
- No Arctic grayling were captured in either system.
- The traps were very difficult to maintain during spring freshet conditions, and were probably installed to late. If substantial numbers of grayling had been moving into or out of the streams some fish should have been captured.
- Trapping of Arctic grayling during spring spawning migrations is extremely difficult because the fish may start moving before the ice breaks up.

1994 Arctic grayling Classification

- A series of letters and information were sent to the Provincial Indigenous Species Biologist urging consideration of classifying Arctic grayling in the Williston Watershed as an endangered species.
- Arctic grayling received endangered status (red listed) in 1995.

1995

1995-98 Table and Anzac Rivers Arctic grayling study.

Objectives The objective of this project was to gather life history information on Arctic grayling and determine enhancement opportunities in two physically similar watersheds. The Table River was historically an important system for Arctic grayling but intensive industrial activities and road access may have resulted in a decline in populations. The Anzac River is relatively pristine, and still supports a good population of Arctic grayling. This project was also intended to provide the baseline data for long term evaluations, as recommended in the "Arctic grayling enhancements review contract".

1995

- Population estimates of 9 and 34 fish / ha were made on mainstem habitats, and strong preference for pool habitat was documented for adults.
- For the first time a small number (12) of Arctic grayling fry were captured, in shallow mainstem riffle habitat.

1996

- Detailed surveys of adult Arctic grayling habitat utilisation / preferences were conducted.
- Young of the year grayling distribution, and preliminary habitat utilisation evaluations were completed.
- The information gathered was provided to habitat protection staff to help protect this critical habitat, which had not been identified previously.
- Inspections were conducted on a number of potential habitat improvement sites with a BC Environment hydrologist, a Ministry of Forests engineer and a local engineering contractor. preliminary plans were developed to improve the sites and one debris jam was removed, using a helicopter and grapple.

1997

- The spring floods were more severe and lasted longer than normal.
- This project determined habitat utilisation, distribution and relative growth rates of young of the year and adult grayling in the Table and Anzac rivers.
- Age class distribution, verification of ageing techniques and genetic samples were also collected.
- The observed distribution of newly hatched grayling fry was documented with the highest numbers observed in side channel areas of the Anzac River.
- Upstream fry distribution coincided with an increase in substrate size
- No fry were found in the Parsnip River.
- Grayling fry were found primarily in low velocity, shallow near shore habitats of the mainstem and in isolated pools and backchannels.
- They were frequently associated with YOY bull trout and burbot.
- High numbers (compared to the number found in the river) were found in small isolated pools.
- No age 1 grayling were captured in the Table, Anzac or Parsnip rivers either by beach seine or electrofishing.
- Mature adults were found in the upper mainstem and showed a strong preference for pool habitats downstream from steep riffles.
- Grayling showed no inclination to use LWD for cover.
- Two adult grayling tagged in the Table river in 1995 were recaptured in the Anzac River.
- Ageing verification comparing fin ray and scale ages found that 90% of the older individuals were aged within one year, but fin ray ages tended to be older.

1998

- Spring floods were early and less severe than normal.
- Distribution, relative abundance, hatch timing and early growth rates of newly hatch grayling in the Table and Anzac rivers was examined.

- YoY were further upstream in the Table the ever before, hatch dates were earlier and first year growth was greater, and also YoY fry were found in the Parsnip R.
- A key was developed by M. Stamford and Dr. McPhail (UBC) to help identify larval grayling.
- For the first time significant numbers of one year old grayling were captured.
- These juveniles were located in the Parsnip River and genetic samples, distribution, relative abundance, growth and habitat utilisation data was collected.
- All grayling captured in 1998 were implanted with a Passive Integrated Transponder (PIT) tag in order to track future movements and evaluate floy tag losses.
- It appears that most one and two year old grayling from the Table and Anzac rivers rear in the Parsnip River.
- Follow up genetic and PIT tag data will be used to try to corroborate this assumption.
- Three index sites in the Table River and five in the Anzac were established to monitor long term adult population trends.
- Mark recapture methodologies may not be suitable for estimating grayling populations, because the marked grayling moved out of the study area (4 km long sections).
- Scale back calculation data was tabulated to allow comparisons of yearly growth rates with temperature, flow and year class data.
- Additional scale vs. fin ray age verification data was collected and fin ray ages were greater particularly on larger fish (>330 mm F.L.).

1996

1996-97 Arctic Grayling Radio Telemetry

Objective: Determine the spawning areas of Arctic grayling in the Table and Anzac rivers in order that these areas may be documented and protected.

1996

- Radio transmitters were surgically implanted into 25 Table River and 30 Anzac River grayling.
- Tissue samples were taken from all fish for genetic analysis.
- Six telemetry flights were conducted from September 1996 to March 1997 to determine the winter distribution of the fish.
- Most of the Table River fish had moved to overwintering areas by September 24th.
- The tagged grayling were still in the Anzac River on Sept. 24th but only two remained by November 6th.

- Most of the Anzac River fish overwintered in the Parsnip River downstream from its confluence with the Anzac.
- There were no concentrations of fish at a single site and a small number of fish moved short distances during the winter.

1997

- Arctic grayling were tracked through radio telemetry until October for a total period of thirteen months.
- Migrations to overwintering areas, overwinter habitat utilisation, migrations to spawning areas and migrations to summer feeding areas were all documented.
- The greatest distance travelled was 245 km.
- Fish moved out of the Table River in September and out of the Anzac River in October to overwinter in the Parsnip River.
- Four fish were located in the Reservoir, but did not return to spawn.
- Approximately 30% (6 of 18) of the grayling appear to have spawned in rivers other than where they were tagged.
- There appeared to be a preference to spawning in multi channelled areas of the mainstem of the Anzac and Parsnip Rivers.
- Spawning coincided with spring freshet conditions and as such it was impossible to obtain detailed information on spawning habitat.
- Detailed information was gathered on the distribution of newly hatched fry in both systems, which confirmed spawning distribution.
- Spawning extended upstream until the substrate became dominated by cobble. The numbers of fry observed were too low to provide reliable information on the location of the main spawning areas.
- There were poor survival rates of radio tagged fish, particularly from the Table River.

1998

Funding for this radio telemetry, through FRBC was no longer available so the project was not continued.

1996-99 Arctic Grayling Genetics

Objective: Examine the genetic structure and degree of similarity of grayling populations within the Williston Reservoir watershed in order to provide baseline information for future projects. Determine if genetic markers can be found that can be used to distinguish between different stocks within the watershed.

1996

- Tissue samples were collected from the Mesilinka (60) Anzac (30) Table (30) and Nation (27) rivers.
- A small number of samples (<10) were collected from 6 other sites.

- Thirty samples were collected from 6 sites in the lower Peace River and 55 samples were received from sites in Alaska and northern B.C.
- Initial analysis did not detect any genetic variation within watershed populations but there were detectable differences between Williston and outside populations.

1997

- Samples were collected from five rivers within the watershed, from two rivers in the Peace River drainage downstream from the reservoirs and two samples were obtained from Alaska.
- More analysis using mitochondrial and microsatellite DNA markers will be necessary before this is conclusive.

1998

- Samples were collected from newly hatched fry from a number of rivers within the watershed.
- Analysis of the data has found genetic markers that can be used to distinguish between Williston and other stocks.
- Other markers have been found, that may be able to distinguish different stocks within the watershed.

1999

- Analysis of the data is continuing and the results will be presented at the "Arctic grayling workshop "in January 2000.

1997

Continuation of previously initiated projects (Mesilinka Stream fertilisation, radio telemetry, and habitat utilisation in the table and Anzac Rivers).

1998

Continuation of previously initiated projects (Mesilinka Stream fertilisation, and Table and Anzac Rivers studies).

1998-00 **Arctic grayling Workshop**

- Process initiated in 1998 to hold an Arctic grayling workshop in Prince George in January 2000.

1999

- A mailing list and call for paper has been sent out and arrangements have been made for a location and additional sponsorships.

1998 **Development of and Arctic grayling Management Plan**

- A draft management plan in a format similar to Provincial Species Management Plans was developed and presented to the Technical Committee for review.

1999

1999 **Review and summery of previously gathered information data gap analysis.**

SYNTHESIS OF ARCTIC GRAYLING DATA FROM WILLISTON WATERSHED PROJECTS AND FROM THE PUBLISHED LITERATURE

Reproduction

Literature *(References 3, 6, 7 8, 9, 22, 23, 38, 39, 40, 45, 57, 67, 68, 69, 82, 87, 90, 91, 97, 98, 101, 108, 111, 121, 122,123,124, 128, 130,133, 134, 136)*

- Grayling are early spring spawners.
- Spawning is initiated when water temperatures reach 4 ° C, and continues from mid May to mid June during the spring high flow period.
- Usually spawn over clean gravel in water 30-80 cm in depth but a wide range of conditions, locations and habitat types have been reported.
- Spawning habitat preferences (from Alberta) are reported as: depth- range 16-40 cm, preference 26-30 cm; substrate size range <2-64mm, preference 17-64mm ; focal point water velocity range 0.2-0.8m/s,preference 0.4-0.8m/s.
- In some systems the majority of fish may spawn at one location, in other systems spawning may be widely distributed.
- Both sexes are highly polygamous.
- Males arrive first and defend territories in riffles.
- Males will spawn with any female that swims into their territory, females that are not inclined to spawn are driven away.
- Females move about the stream and may spawn with many different males.
- Males defend a territory for approximately one week, females are assumed to complete spawning in three to four days.

- Grayling do not build redds, but the eggs are usually deposited at a depth of two to three cm in small gravel.
- Egg mortalities can be quite high, but fecundity ranges from 3,000 to 14,000 eggs, with mean a fecundity of about 7,000 per female.
- 125-200 degree days to hatch or two to four weeks depending on temperature.
- Sexual maturity starts at 270mm, all are mature by 300mm F.L.
- Male and females mature at the same age, normally at age four to six and for slower growing longer lived stocks at age six to nine.
- May find stock mature smaller / younger under heavy exploitation.
- May have several genetically isolated populations utilising the same system.

Williston: *(References 14,15)*

- Spawning occurred just after the peak of the spring freshet and continued from late May to late June in 1997.
- In 1998 spawning was approximately one month earlier (1997 freshet was longer and more severe than "normal" and in 1998 the spring high flows were earlier and less severe.)
- No data is available on specific habitats used for spawning but limited use was made of small tributaries and multi channelled areas of the mainstem were preferred.
- Males arrived at spawning areas first, and remained at one location for one month.
- Some females remained near "spawning" area for up to one month but others moved slowly upstream throughout the spawning period.
- Spawning did not occur in areas where the mainstem substrate was dominated by cobble or larger substrates but in the lower Table River some areas with a high fines content were utilised.
- No data on incubation is available but in the Sukunka River (adjacent watershed) 206 degree days were required to hatch.

Data Gaps

- Main spawning areas in the watershed need to be identified.
- Methods… need to be developed to identify spawning areas - radio telemetry should be effective but is very expensive vs. fry distribution methods which are less expensive but require ideal conditions.
- Spawning habitat types (may be stream specific and rearing habitat proximity is probably very important).
- Timing… temperature and stream flows.
- Index method to determine spawning success.
- Gather age / size at maturity data in Williston
- Effects of stream flow on survival and site selection.
- Spawning area affinity, site fidelity, factors that control site affinity.
- Fecundity in this watershed.
- Incubation Sukunka 206 degree days.

Early Rearing

Literature *(References 3, 6, 8, 22, 23, 37, 38, 39, 40, 57, 63, 64, 68, 82, 91, 97, 101, 121, 122,130,132)*

- Emergence two to four weeks (125-200 degree days) at a size of seven to fourteen mm.
- Fry have limited swimming abilities.
- Require a constant and abundant food (chironomid larvae or other small benthic insects).
- Concentrate in dense schools in alcove habitat (shallow low velocity), immediately downstream from spawning areas.
- Downstream migrations have been reported but most fry remain near hatching locations.
- Proximity to sheltered rearing habitat may be more important than the spawning habitat itself.
- Very vulnerable to flooding and mortalities can be very high either by turbulence or indirectly by starvation if displaced downstream.
- Not uncommon for entire year classes to be lost.
- Rear in very shallow low velocity areas along the stream margins usually over cobble substrate.
- Vulnerable to stranding if water levels drop.
- Become territorial and move to deeper and higher velocity habitats as the summer progresses.
- Riffle habitats often utilised.
- Very fast growth may exceed 100mm by late summer norm ~ 70-90 mm.

Williston *(References 14,15)*

- Emergence size 11-14 mm.
- May disperse downstream.
- May form dense schools near spawning areas but usually small groups.
- May be mixed with schools of smaller longnose suckers.
- Remain in shallow low velocity near shore habitats for the first summer.
- Preferred habitat newly hatched , <6cm depth <.03m/s velocity, gravel silt substrate -after hatching to late summer <15cm depth, <0.15m/s velocity, silt to cobble substrate in late summer.
- Associated with young of year burbot and bull trout in Anzac.
- Very low densities (max 30-80/km or 30-40/ha).
- Movement to deeper fast habitats not found in Table or Anzac.
- Vulnerable to stranding, it appears a high percentage of year class can be lost.
- Growth highly variable September average 46-72mm but this depends on the length of the growing season and stream flows.
- Back calculated sizes at first annulus are similar to other areas but on the small side.

Data Gaps

- Food.
- Dispersal mechanisms.
- Effects of stream flow on early survivals.
- Importance of suitable habitat on survivals.
- Effects of land use practices on critical flows and habitats.
- Predation (burbot?).
- More density data for index sites.
- Effects of stream flows on survival and growth.
- Early rearing possible bottleneck in production.
- Competition.

Habitat Utilisation

Literature *(References 3, 6, 7, 8, 9, 22, 23, 24, 25, 38, 39, 40, 43, 57, 58, 67, 68, 76, 78, 82, 83, 84, 87, 90, 91, 97, 101, 102, 122, 123, 124, 130, 132)*

- Utilise a wide variety of habitats from large mainstem rivers to small alpine streams.
- Limited use of lakes in British Columbia but lake utilisation by adults is common throughout the rest of the species distribution.
- Usually associated with clean cold waters and actively avoids turbid areas.
- Tolerant of high temperatures (upper lethal temperature 25°C optimum 8.5-17°C).
- Can survive winter oxygen levels of less than 1ppm (optimum >3ppm).
- Tends to segregate by age class with largest adults in the upper reaches, sub adults mid river and juveniles in the lower river.
- Actual macro habitat utilisation data limited to predictive models.
- Overwinter habitat information is limited.- large mainstem tributaries or lakes.
- Very limited information on specific habitat use of age 1 year class.

Williston *(References 4, 14,17, 20, 78)*

- Historically most numerous and widespread species.
- Only species to be found in high numbers in steep gradient habitat.
- Tended to be more predominant in cold clear systems, rainbow trout more predominant in warmer streams.
- Segregate by age class in some systems.
- Adult macro habitat preference- pools or glides >80cm in depth, particularly downstream of long steep riffles.
- Limited use or association with woody debris.
- Segregated by size, with largest individuals utilising deepest area adjacent to the thalweg smaller individuals along margins and may utilise pool "tail out".

- Almost no use of riffle habitat has been observed, but riffle utilisation was mentioned in "Bruce and Starr".
- Will concentrate (10-50 fish) in deep pools in late summer.
- Concentrations are usually in association with mountain whitefish.
- Age 1+ are found almost exclusively in slow glide habitats, preferred depth 0.6-1.0m over gravel or cobble substrate.
- 1+ do not appear to utilise smaller systems or tributaries.
- The only notable concentrations of 1+ grayling found were in the Parsnip River.
- Overwinter habitats adults move downstream to large mainstem or reservoir.
- Overwinter -utilised wide variety of habitats frequently downstream of higher velocity areas some fish observed in very shallow (estimated winter depths <1.0 m) habitats.
- Some fish exhibited movement throughout winter but most remained at one location December to March.
- In winter adults frequently occupied shallow higher velocity areas associated with riffles, islands or mid channel bars.

Data gaps

- Associations with other species.
- Habitat utilisation of 1+ age class (additional information from other systems).
- Utilisation of the reservoir by age class.
- Overwinter habitat of younger age classes.
- Determine if Table Anzac data is applicable to other systems.

Migrations

Literature *(References 3, 6, 7, 23, 38, 39, 40, 59,70, 76, 81, 82, 87, 90, 91, 97, 100, 121, 122, 128, 130, 133.)*

- Many populations migrate downstream in September (July-December) to large mainstem habitat or lakes to overwinter.
- Distances travelled are highly variable but 100 km is not unheard of.
- Some fish, particularly a portion of the younger year classes may remain in tributaries.
- Migrations to spawning areas start as water temperature starts to rise frequently before spring break up.
- Annual site fidelity for spawning has not been documented but is suspected.
- Summer feeding site fidelity has been documented.
- Adults may not spawn in summer feeding streams.
- Spawners migrate to summer feeding area soon after spawning.
- Non-spawning fish will move directly to summer feeding areas from overwinter areas.

Williston *(References 15)*

- Adults move downstream to overwinter in large mainstem habitats or the reservoir areas in September and October.
- Historically large concentrations were observed at the W.A.C. Bennett Dam in winter.
- Distances travelled to overwinter locations could have been > 200 km.
- Spawning migrations started when water temperatures started to rise before spring break up.
- 30% of the radio tagged fish did not spawn in the stream where they were tagged.
- Data suggests a different spawning distribution in 1998 compared to 1997 possibly because of flow conditions.
- High site fidelity between years for summer feeding locations has been observed but adult summer distributions may change with water levels.
- Appear to be stopped by barriers that are passable to Rb and Bt.

Data Gaps

- Spawning site fidelity.
- Movements between systems.
- Migrations of juveniles.
- Juvenile overwinter habitats.
- Impacts of the reservoir - increase in straying?
- Winter reservoir utilisation by different age classes.

Food

Literature *(References 3, 21, 40, 44, 98, 113, 121, 122,132, 136)*

- Young fry feed on larval chironomidae, sumuliidae, plecoptera, and other benthic insects.
- As they grow diet shifts to larger terrestrials and invertebrate drift.
- Adults tend to feed primarily on surface or drifting insects but some authors report utilisation of benthic insects.
- In lakes zooplankton, midge pupae, and gastropods.

Williston *(References 1)*

- Adult insects and their aquatic stages formed the bulk of prey taken by older grayling in the Parsnip River.
- Experiment is being conducted to determine the affect of increased food supply on grayling but other species are showing greater positive response.

Data Gaps

- No information on food.
- Food availability in reservoir.

Age and Growth

Literature *(References 3, 6,7, 8, 9, 22, 23, 25, 27,28,29,30,31,38,39, 40, 46,47, 51, 52, 59, 60, 62, 70, 76, 82, 87, 90, 91, 97, 99, 104,105,1 1, 120, 121, 122, 123-128, 130, 131 132 33 136)*

- Age verification - otoliths are the most reliable method, scales can underestimate because some stocks may not have sufficient growth in the first year or the outer bands may not be visible in older individuals -fin ray determinations are better than scales but not as good as otoliths.
- No difference was found in scale / otolith ages from the Sukunka River for fish 1-7 years of age.
- Difficult to compare age compositions of populations because of sampling bias and segregation of age classes.
- Generally northern slow growing populations are composed of a higher percentage of older individuals than faster growing southern stocks or highly exploited stocks.
- Fish can live past twenty years and in unexploited northern stocks a high percentage of the population can be over eight years old.
- Most stocks are dominated by fish from three to eight years old.
- Growth rates are highly variable but well documented.

Williston *(References 1, 4, 11, 12, 13, 14, 15, 20, 66, 71, 73, 75,78, 91, 138)*

- Fin rays provide more reliable estimates of age than scale samples, but until fish reach approximately 330 mm F.L. or five years of age scale ages appear to be as accurate as fin rays.
- Most Williston stocks are dominated by 3 to 6 year old fish, but the faster growing Nation River (warmer system) stock is dominated by age 3 and 4 year old fish.
- Size at age has decreased since the mid 70's particularly for ages 3 and 4.
- Parsnip River grayling size at age has remained the same since the 1970's, possibly because they were not influenced by the reservoir.
- Williston watershed size at age data is in the middle of the pack for BC/Alaska/NWT stocks.
- Back calculation and young of the year data show yearly growth variations, are strongly influenced by stream flows.

Data Gaps

- Detail analysis of effects of stream flow on growth.
- More Young of the Year data.
- Gather data on effects of different life history patterns on growth.
- Determine effects of stream fertilisation on growth / survival.

Genetics

Literature *(References 3, 56,77)*

- Some data suggests multiple distinct stocks utilising the same systems.

Williston *(References 119)*

- Low haplotype diversity and low heterozygosity suggest severe genetic bottlenecks during colonisation.
- No markers have been identified that can be used to separate individual stocks but the various populations do exhibit different allele frequencies.
- The Nation River stock (warm system potentially isolated by a barrier in the lower river) appears to be unique.

POTENTIAL FACTORS LIMITING ARCTIC GRAYLING PRODUCTION

It is highly probable that the factors limiting Arctic grayling production may be differ between systems and may change from year to year depending upon environmental conditions. A lack of suitable habitat for one life history stage does not preclude use of a system by other life history stages. A combination of factors such as overfishing, degraded habitat and competition from other species, could have impacts which are much greater than the sum of the individual impacts. The fry mortalities caused by flooding and stranding are natural and seldom effect health populations over the long term, but could push populations that have been reduced by overharvest and habitat degradation beyond a point where natural recovery is possible. Similarly, predation by Bull trout would have little effect on a healthy population but if numbers were reduced, selective predation could prevent a population from recovering.

Egg Deposition

Number of Spawners

- Limiting in some smaller systems and in systems where overharvest or other factors may have eliminated most of the adult population.
- Could be a critical level after which populations cannot recover.

Condition (size) of the Adults

- Comparable to other systems although maximum size is smaller than some areas.

Access to spawning Areas

- Not limiting except in smaller tributaries (beaver activity, culverts) or where woody debris has blocked access to some smaller tributaries entering the reservoir.

Available spawning habitat

- Quality does not appear to be limiting in most systems but there may possibly be some degradation in heavily logged areas.
- Quantity of spawning habitat available is naturally significantly less than was available prior to the formation of the reservoir, but the habitat available after flooding did support much higher numbers fish than are today.

Hatching

Water Temperature

- Not limiting.

Dissolved Oxygen

- Not limiting.

Suitability of spawning gravel

- May be limiting in some systems or some reaches.

% fines in the substrate

- May be limiting in some reaches, but grayling are probably less susceptible to siltation during incubation than other salmonids.

Water velocity

- Freshet conditions may cause bed movement in many areas resulting in high mortalities particularly if the adults spawn in single channelled mainstem habitat. grayling are much more vulnerable than other salmonids.

Stranding

- Falling water levels between spawning and hatch could potentially result in high moralities in many systems. more vulnerable than other salmonids.

Early Rearing

Water flow levels

- Flood levels just after hatching may result in very high moralities in most systems.
- Rapid drops in water levels could strand a high percentage of the population.
- Late or extended spring floods may result in reduced growth during the first year.

Water velocity
- Newly hatched fry must find low velocity areas soon after hatching.
- Is limiting during floods and in many reaches.

Suitable sheltered rearing habitat
- Concentrations of spawners appear to be correlated with areas of sheltered rearing habitat.(literature, Table & Anzac).
- May strongly influence selection of spawning areas.
- May limit production in some systems or reaches.
- Probably one of the most important factors.

Food
- Limited information on the availability of food for early rearing.
- These rivers support significantly fewer fish that they did historically and growth rates appear to be at close to maximum levels for water temperatures.
- Probably not limiting at present population levels.

Predation
- Because of the size, and behaviour of the fry it is highly likely that they have a wide variety of predators.

Competition
- There are very low densities of all fish species present in these streams.
- The literature suggests that in some areas, competition from introduced species (Brown, brook or rainbow trout) may substantially reduce survivals of newly hatched fry.
- Increased water temperatures in some streams and in the reservoir may give a competitive advantage to other species.
- Rainbow trout in Williston reservoir are at the northern limit of their range and Arctic grayling are at their southern limit. Rainbow trout growth rates in the reservoir are essentially the same as they were in the mid 1970's. The extended growing season and warmer water temperatures in the reservoir may give rainbow trout a competitive advantage.

Stranding
- Because Arctic grayling fry concentrate in very shallow low velocity areas there is the potential for large numbers of them to become stranded with falling water levels.
- Our observations strongly suggest that this can affect a very high percentage of the young of the year fry.

Juvenile Rearing

Water temperature
- Warmer water temperatures may give competitors an advantage.

Dissolved oxygen
- Not limiting (grayling tolerate low oxygen levels better than most species).

Available suitable habitat
- Could be limiting in smaller systems entering into the reservoir i.e. if 1yr. old juveniles cannot compete in the reservoir environment.

Available suitable wintering habitat
- Does not appear to be limiting in the Table and Anzac or most other systems because of the mobility of the species.
- Very difficult to determine overwinter survivals because of the mobility of this species.

Food
- Does not appear to be limiting as most of the streams supported much higher numbers of fish historically.

Predation
- Does not appear to be limiting in most situations.
- Could be a factor in rivermouth areas with limited cover.

Competition
- Does not appear to be limiting although in warmer systems (Nation, Mason) or the reservoir competition from rainbow trout or species better suited for the reservoir could be a factor.

Adults

Food
- Not limiting in streams but may be reduced by habitat degradation. (The dramatic increase in food available in the Mesilinka River does not appear to have resulted in a significant change in Arctic grayling populations, however because of the migratory and distribution patterns the benefits of fertilisation of small areas may be masked.)
- Possibly limiting in the reservoir.

Habitat availability
- Grayling appear to have a preference for deep pools in late summer. This could be limiting in some systems, although streams without deep pools simply might not be used for summer feeding areas.
- Concentrations of adults in deep pools during low water conditions may result in decreased growth rates.

Predation
- Not limiting in most instances but information is limited.
- Bull trout predation could prevent depressed populations from recovering if bull trout were to selectively feed on grayling over mountain whitefish.

Angling

- Historically may have been a significant factor in the decline of many stocks.
- Now has minimal negative impacts because of angling closures.
- Illegal harvest could have dramatic effects on depressed stocks because of the propensity of large adults to congregate.

Migrations

- Many grayling may have been unable to find their natal streams after migrating to the reservoir to overwinter. Rainbow trout were reported to be unable to find spawning streams after the reservoir was formed, and straying is still evident. This could also be the case with grayling.
- Initially many fish were probably have been lost to the system through entrainment.
- Road construction, culverts and beaver dams or debris at stream mouths could block routes to spawning areas and reduced the amount of habitat available. But most stocks now appear to utilise large mainstem habitats rather than smaller tributary streams.
- Debris at the stream mouth areas may have blocked access to smaller streams entering the reservoir.

Competition

- The change from a river to a reservoir may have given other species a competitive advantage in the reservoir.
- Elevated water temperatures may give other species an advantage. Rainbow trout appear to displace Arctic grayling from prime feeding locations in warmer systems.
- Historically grayling appear to have been predominant in cold systems.

Overwintering habitat

- Because of the mobility of this species and the availability of large deep mainstem habitats and the reservoir, the availability of overwintering habitat does not appear to be a problem.

Critical Factors

The most critical factors appear to be:

1. Egg mortalities because of flooding (bed movement);
2. Egg mortalities because of stranding (falling water levels);
3. Fry mortalities because of flooding;
4. Fry mortalities because of stranding;
5. Limited alcove habitat (shoreline complexity) in some areas;
6. The change from a river to reservoir may have given other species a competitive advantage;
7. Juvenile rearing habitat of small systems that drain directly into the reservoir (if juveniles have low survival rates in the reservoir):

RECOMMENDATIONS

If the reservoir played an important role in the demise of Arctic grayling stocks then this species should be at the top of the priority list for the PWFWCP.

The report "A strategic plan for the conservation and restoration of Arctic grayling in the Williston Reservoir Watershed" presents a wide range of objectives and strategies for management of this species.

In order to be effective this program will need to focus on attainable goals and direct efforts towards gathering information that will clearly help to conserve and enhance grayling populations and their habitats within this watershed. The gathering of life history and distribution information should continue and the establishment of index populations to monitor population trends should be completed. Much of this type of information is necessary for land use planning and as such outside funding or partnerships should be sought. Experimental manipulations should be conducted to evaluate the most promising enhancement or restoration techniques and to determine which factors have the greatest impacts on grayling populations. Genetic studies have not yet identified markers that can be used to determine if the remaining populations are unique stocks. It would however, be irresponsible not to treat the remaining populations as unique stocks until conclusively proven otherwise.

The objectives this program should focus on are:

1. Preventing further declines in the remaining populations.
2. Enhancing or restoring production from existing populations.
3. Determining if, and how stocks can be reintroduced back into historical habitats.

1. Prevent Further Declines

Catch and release angling regulations have been in place since 1996 which, assuming we have reasonable compliance, should stop any overharvest problems. However, providing information on areas where adults congregate, to be incorporated into access management plans should further reduce potential problems. The current Forest Practices Code should also significantly reduce further habitat degradation. However, there is no guarantee that this will prevent further declines in the stocks. To ensure populations are protected, key spawning and early rearing areas must be identified and afforded additional protection (larger buffer areas etc) and index sites should be established in several systems so that the status of key stocks can be monitored. Information gathered by this program should be incorporated into the land use planning process and into habitat protection guidelines to ensure the protection of key areas.

Strategies

- Determine the distribution, relative abundance and life history strategies employed by the different "stocks" throughout the watershed.
- Identify prime spawning and early rearing areas (both specific sites and habitat types) of the remaining stocks either through radio telemetry or fry distribution surveys.
- Identify areas where adults congregate and are vulnerable harvest.

- Start long term year round stream temperature monitoring to assist in spawning timing and fry distribution studies.
- Evaluate the effects of logging on stream flows. (seek outside funding as this is not necessarily the mandate of the PWFWCP).
- Evaluate the feasibility of creating controlled flow spawning and early rearing areas to test the effects of stream flows on survival rates. (seek outside funding).
- Evaluate the effectiveness of the Forest Practices Code at protecting grayling populations (seek outside funding as this is not necessarily the mandate of the PWFWCP).
- Insure that habitat protection concerns are incorporated into The Land Use Planning Process.
- Insure that the findings of this program are incorporated when habitat protection guidelines are developed.
- Retain stringent angling regulations and promote public education.
- Establish index sites in key systems to monitor changes in adult populations and recruitment.
- Incorporate experimental manipulations that do not just look at impacted vs unimpacted habitats, but also include "enhanced or restored habitats as well. It is equally important to determine how to improve / restore habitats as it is to prevent degradations.

2. Enhancement or restoration of existing stocks and habitats

Strategies

Prior to any enhancement / restoration work we should attempt to answer basic stock management questions such as:

- Are there separate stocks within the watershed?, within systems?
- Is there site fidelity for spawning / summer feeding areas?
- Are differing life history and migratory patterns genetic, learned, or random?
- Which factors may limit production.

Or

Incorporate studies to answer these questions into enhancement / restoration projects. In fact evaluations of enhancement / restoration projects will probably be the only way to answer many of these questions.

To help answer these questions the most up to date genetics and laser ablation techniques should be employed as well as co-operation with other researchers in this field.

Areas to focus on for "enhancement / restoration" should concentrate on recruitment and early life history and would include:

- Recruitment - groundwater fed or control flow side channels for spawning and early rearing, perhaps shoreline complexing near key spawning areas and fry salvage to improve survival rates. Investigate the potential of fish culture techniques (incubation and short term rearing of wild fish to be released back into their natal stream) to augment depressed stocks.
- Habitat - possibly habitat improvement of stream mouth (embayment) areas or shoreline complexing.

- Food - stream fertilisation or embayment enhancement.
- Predation - determine the effects of bull trout predation on depleted stocks.

3. Determine if and how stocks can be reintroduced back into historical habitats

The reason for the disappearance of stocks from so many streams in the early 1980's has not, and may never be answered. Anecdotal information indicates that overfishing may have been a prime reason for the declines. Large numbers of adults congregated at the dam during the winter and many may have been lost through the dam. Adults that overwintered in the reservoir could have strayed or have been delayed on the spring spawning migrations potentially resulting in reduced recruitment. One and two year old grayling do not appear to rear in medium and small streams, but drop downstream to rear in larger rivers. These age classes from many streams would have been forced to rear in the reservoir and may have experienced reduced growth or survival rates once the floating debris was cleared and reservoir productivity declined in the early 1980's.

In order to determine if stocks can be reintroduced back into their historical streams, information will have to be gathered on reservoir utilisation. It is possible that the 1+ age class, because of their apparent propensity to move downstream out of smaller streams to rearing in larger rivers were unable to compete in the stream mouth areas of the reservoir. However, if the productivity of these areas was enhanced, survival and growth rates might be improved. A program should be initiated to evaluate Arctic grayling utilisation of the reservoir in the Mesilinka embayment area.

The reintroduction of Arctic grayling back into systems that historically supported populations will be in part dependent upon results of the other activities. However, this does not preclude the establishment of populations in small isolated lakes. This would serve two purposes, to insure the preservation of the genetic makeup of remaining populations, and as a source of fry or eggs for future reintroduction's. At the present time, there are no grayling populations that could serve as a donor stock and it would take a minimum of five years to establish a new donor source. Evaluations of factors affecting growth and survival could possibly be much simpler to determine in a system where the stocks have been reintroduced. No amount of passive observation will provide the answers about how to re-establish grayling back into systems where they have been lost. A management decision is needed to make this a priority objective.

Strategies

- Develop a list of small lakes that can support grayling populations.
- Initiate a small scale transplant program into the most promising lakes as pilot projects.
- Establish a lake population for each of the river systems that still support grayling populations.

Five Year Project Strategies

To accomplish the aforementioned objectives we should concentrate or efforts in the following areas:

- Identifying spawning and early rearing areas in systems that may be impacted during the next few years.
- Documenting habitat utilisation and migrations of the 1+ ear class.
- Evaluating reservoir utilisation.

- Establishing index sites to measure recruitment and adult populations, particularly in systems, which may be subject to change e.g. logging or habitat restoration.
- Establish index sites on one population that has had minimal impacts.
- Determining methods to identify different "stocks"(genetics or laser ablation).
- Evaluate the feasibility of fry salvage as a method to increased recruitment.
- Develop "donor populations" that can be used as a source of fry or eggs for future experimental manipulations or reintroductions.

Methods will have to developed that are neither time consuming or costly to identify spawning and early rearing habitats.

Care should be taken to develop index sites and methods that do not seriously impact the time and monetary limits of the program.

If donor populations can be established for the various populations with minimal time and monetary commitments these should be pursued.

Also great care must be taken not to negatively impact the remaining stocks by increasing mortalities through over handling (excessive electrofishing, marking, tagging, etc).

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